PRELIMINARY CARTOGRAPHIC ANALYSIS OF THE PATHFINDER LANDING SITE USING VIKING ORBITER IMAGES. Thomas C. Duxbury, Jet F'repulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109

An initial stereo photogrammetric analysis of Viking Orbiter 1 (VO-1) images within the central portion of the expected Pathfinder landing ellipse was performed. These images were taken on Revolution (REV) 4 and included 4 overlapping images looking forward from nadir about 16 deg and four additional overlapping images of the same site looking backward from nadir about 16 deg. The attitude of VO-1 had been maneuvered off of the normal sun-Canopus 3-axis stabilized configuration to align the footprints of the images along the orbit ground track.

During both of these sequences, camera pointing has held fixed relative to the spacecraft, enabling the twin orbiter cameras to lay down strips of images with overlap between the twin cameras and overlap along the direction of orbital motion. The camera design (focal lengths, fields-of-view, readout rates, etc.) and mounting alignments were chosen specifically to enable such imaging sequences.

Maneuvering the attitude of the spacecraft had the advantage of providing the optimal footprints of the orbital images to build up the overlapping strip of images but had the disadvantage for stereo photogrammetry by providing less accurate camera pointing information. In the normal sun-Canopus 3-axis attitude configuration, sun sensors and the Canopus tracker measure the spacecraft attitude to an accuracy of 0.3 deg (1 sigma). Reconstructing the attitude of the spacecraft when maneuvered off of the sun and Canopus relied upon the inertial gyro angular rate readouts which gave a reduced pointing accuracy of about 0.5 deg (1 sigma).

One major reason for redoing the cartography of the Pathfinder site or any other site on Mars is that recent work (Dr. David Smith (GSFC), et. al. and Dr. Alex Konopliv (JPL)) significantly improved the Mars gravitational field and orbits. Processing very long arcs of Mariner 9, VO-1 and VO-2 radio tracking Doppler data has produced new orbits having precision of about 100 m along-track and cross-track and 50 m in radius. This represents an order of magnitude or more improvement over the old orbits.

The cartographic processing included:

1) obtaining the timetag, camera pointing and orbit information of the 8 overlapping, stereo images
2) establishing a control network of 152 surface features within an area of 32.8 to 34.2 deg west longitude and 18.2 to 20.2 deg north latitude
3) measuring the reseau locations in each of the 8 images
4) measuring the image locations of the control points in all images
5) producing initial values of the control point coordinates
6) performing the stereo photogrammetric data reduction by using the measured image coordinates of the control points as observations and estimating the control point locations, camera alignments, platform pointing

and orbit corrections

7) interpolating the control network positions to produce a digital elevation model (DEM) within the image coverage
8) registering and map projecting the 8 images to the DEM to produce a controlled photomosaic in the form of a gridded digital image model (DIM)

The VO-I images were obtained from the Planetary Data System produced CD-ROM dataset. The timetags of these images were expressed in Julian Ephemeris Date with a truncation / roundoff error of up to 0.2 s. The camera pointing was given as inertial angles of unknown heritage relative to the Earth Mean Equator and Equinox of B1 950 system. These timetag and pointing data were replaced by data obtained from computer printouts of the original Supplemental Experimenter Data Records (SEDRs) archived at the JPL Regional Planetary Image Facility (RPIF). SEDR timetags were given to a millisecond. The pointing data was taken in the form of scan platform Clock, Cone and Twist angles relative to the spacecraft, derived from the original telemetered spacecraft attitude and platform pointing data.

The spacecraft positions were obtained from Navigation Ancillary Information Facility (NAIF) SPICE SPK Kernels which contained the precision orbit solutions produced by Dr. Alex Konopliv (JPL). The Mars spin axis, prime meridian and mean ellipsoidal surface were obtained from the SPICE PcK Kernel which is based upon the 1994 published recommendations of the IAU (Davies, et. al.). This approach of timetags, platform pointing, new orbits and the latest IAU standards allowed all processing to be performed in the Earth Mean Equator and Vernal Equinox of J2000 system,

Reseau image locations were automatically measured by convolving a simple 2 dimensional digital filter having the shape of a reseau with the images. The measured reseau locations, accurate to about 0.3 pixels (1 sign-la), were used to construct a geometric model between image space and object space, independently for each image. The VO cameras used vidicon tubes for producing images which exhibited the normal beam bending local distortion of up to 2 pixels in position between dark and bright image areas. The reseau measurements give the ability to remove the global effects of beam readout distortions but are too sparse to remove local beam bending distortions acting over small areas. This beam bending limits the planimetric accuracy of the images to a few tenths of a pixel (1 sigma), unlike the CCD's whose image plane distortions are an order of magnitude or more smaller.

Initial control point image location measurements were made manually using computer assisted overlays to an accuracy of 0.8 pixels (1 sigma), near the limiting accuracy of the Viking Orbiter images. The initial Mars-fixed coordinates of each control point were determined by averaging the calculated surface intercept locations for each measurement of a given control point including the effects of image distortions, camera alignments, platform pointing, spacecraft position, and the mean Mars surface. From 2 to 6 measurements of the same control point were used.

Many different data reduction schemes were used in performing the stereo photogrammetric processing. Control point measurement uncertainties were varied from 0.3 to 2.0 pixels (1 sigma). A priori camera pointing uncertainties were varied from 0.1 to 0.5 deg (1 sigma). A priori orbit position uncertainties were varied from O to 100 m (1 sigma).

It was determined that camera pointing uncertainty controls the calculation of the control point absolute positions on Mars. These positions varied up to 5 km in latitude and longitude and 200 m in elevation based upon the a priori pointing uncertainty. The relative control point locations were controlled by the image location measurement accuracies. The orbit uncertainties were small and had little affect on the results. The control point locations exhibited a systematic position offset of about 10 km wsw of their positions given on the USGS map product MTM20032 / I-2311.

The nominal case for discussing results is based upon assuming measurement uncertainties of 1 pixel (1 sigma), camera pointing uncertainties of 0.5 deg (1 sigma) and no orbit errors. This case gave measurement residuals of 0.8 pixels (1 sigma), fixed pointing corrections of about 0.6 deg to the first set of 4 images and 0.5 deg to the seconds set of 4 images and a mean elevation of this area of about -1.0 km with respect to a spheroid having an equatorial radius of 3393.4 km and a polar radius of 3375.8 km. The absolute elevation uncertainties of tile control points were about 0.4 km; however the relative elevation uncertainties were about 30m.

This work will be significantly improved by:

1) including additional, near-nadir looking images taken on REV 4 as well as other near-nadir and off-nadir images taken of the area on REVS 3, 6 and 13
2) using an automated digital correlation technique to measure the control point image locations.
3) compare / share results with USGS and RAND

The additional images will make a significant impact on reducing the effects of camera pointing uncertainty by the square root of N effect as well as some of these new images were taken when the spacecraft was in its more accurate sun-Canopus attitude. The variation in absolute positions of control points should be reduced to less than 1 km in latitude and longitude and less than 50 m in elevation. The use of an automatic image location measurement technique should reduce the measurement errors from 0.8 pixels to 0.3 pixels, the limiting accuracy of the vidicon tubes. The increased measurement accuracy and additional stereo measurements of the control points (up to 12 measurements per point) will also increase the control point location accuracy.

I wish to thank Dr. Timothy Parker (JPL) who helped in obtaining the digital images and Dr. Matthew Golombek (JPL) for discussions of this problem. This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract to the National Aeronautics and Space Administration.